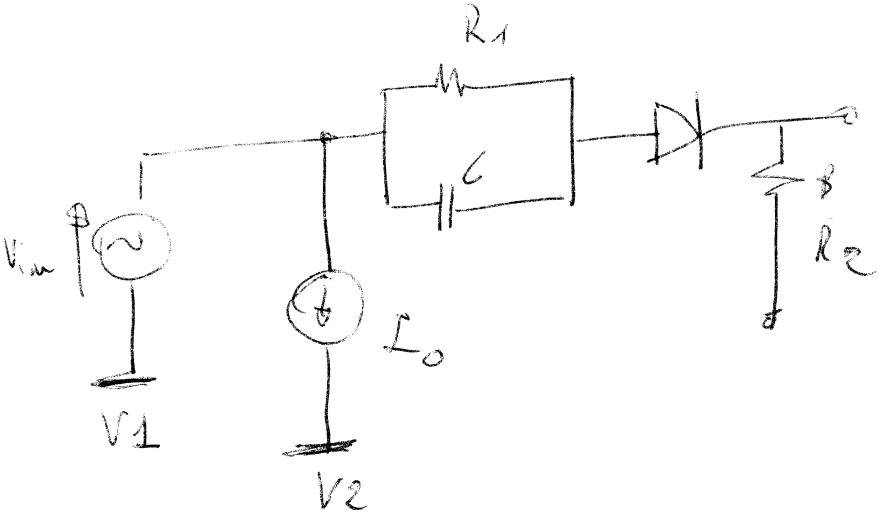


$R_1 = R_2 = 1\,k\Omega$

$C = 1\,pF$

$I_0 = 1\,mA$

$V_2 = 3\,V$

$0 \le V_1 \le 5\,V$

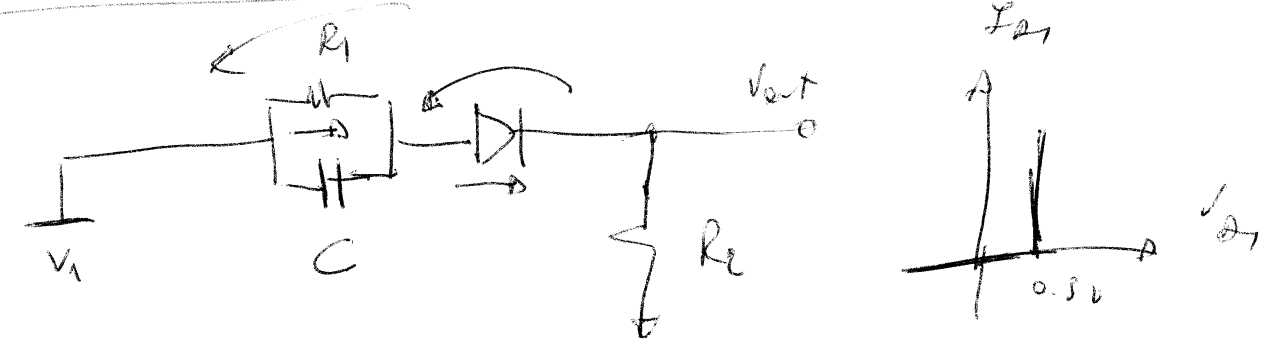
1) V_{out} in funzione di V_1

2) Per $V_1 = 5V$ disegnare il grafico di piccolo segnale e $V_{out}/V_{in}(s)$

3) Per $V_1 = 5V$ Diagrammi di Bode

---

1)

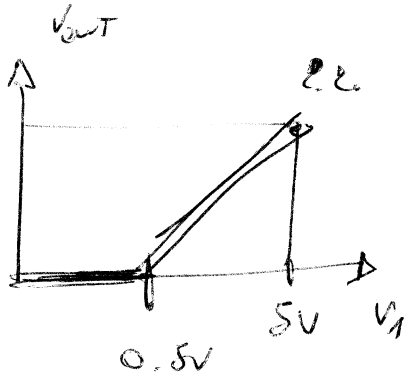


Ipotesi $I_{D1} > 0$

$V_{D1} = V_\gamma = 0.5\,V$

$$\begin{cases} I_{D1} = V_{out}/R_2 \\ V_{out} = V_1 - R_1 I_{D1} - V_\gamma \end{cases}$$

$$I_{D1} = \frac{V_1 - R_1 I_{D1} - V_f}{R_2} \quad (>0)$$



$$I_{D1} = \frac{V_1}{R_2} - \frac{V_f}{R_2} - \frac{R_1}{R_2} I_{D1}$$

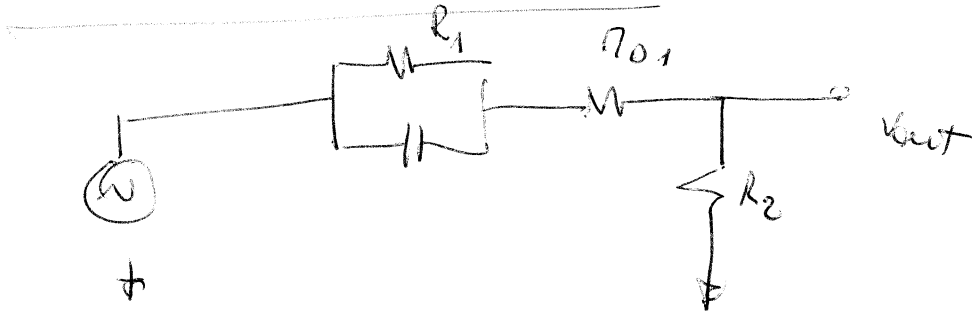
$$V_{out} = \frac{1}{2}(V_1 - 0.5)$$

$$\Downarrow$$

$$\text{se } I_{D1} = \frac{V_1 - V_f}{R} > 0 \Longrightarrow V_1 > V_f \quad D1 \text{ on}$$

$$V_1 < V_f \quad D1 \text{ off}$$

a)



$$I_{D1} = 2.25\text{mA} \quad \text{per} \quad V_1 = 5V$$

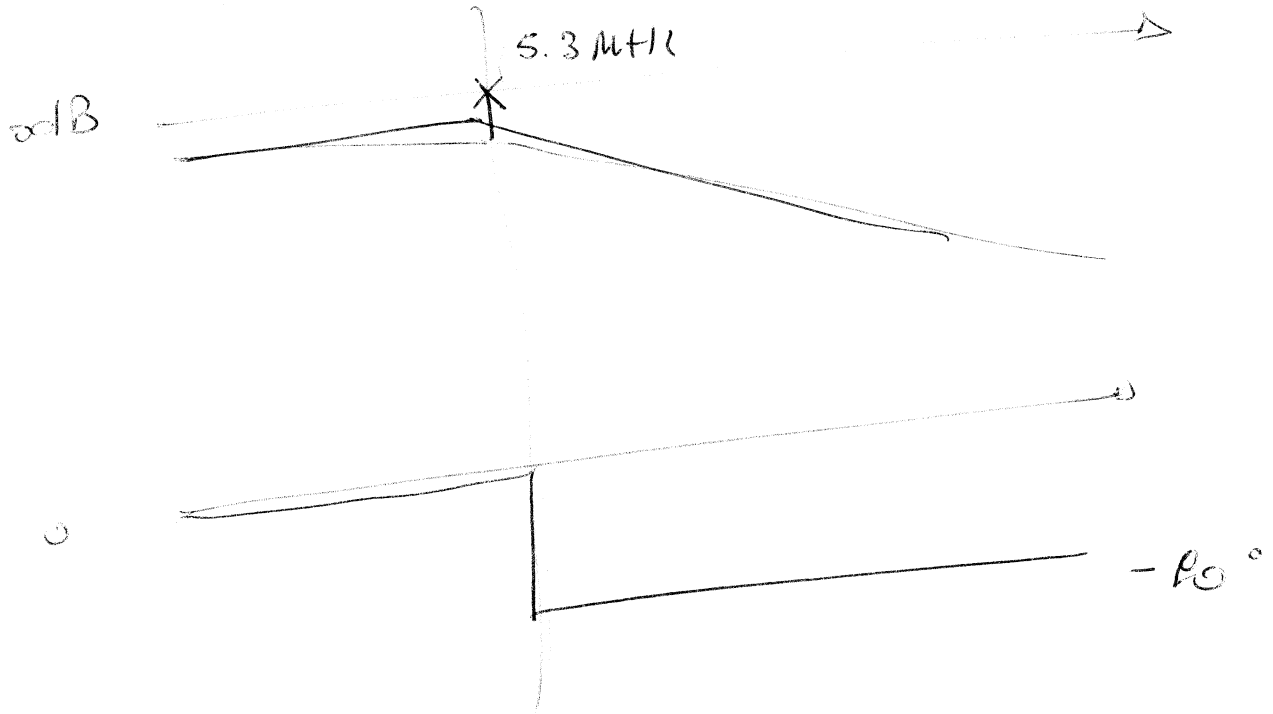
$$g_m = 10\,\text{mA/V} \quad (11\,\Omega)$$

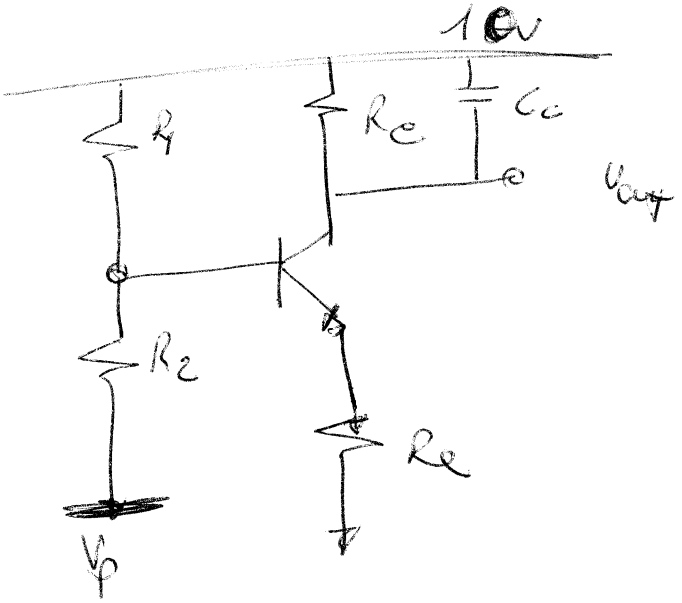
$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_2 + r_{D1} + R_1 \parallel \frac{1}{sC}} = \frac{R_2}{R_2 + r_{D1} + \frac{R_1}{1+sCR_1}} =$$

$$= \frac{R_2}{R_2 + r_{D1} + R_1} \cdot \frac{1}{1 + sC\, R_1 \parallel (r_{D1} + R_2)}$$

$\tau = C \left(R_e \,//\, (R_1 + R_{D1}) \right) = 29\,ns$ (5.3 MHz

3) Diagrammi di Bode





$\beta = 400$ (1)

$C_{in} = \infty$

$R_1 = R_2 = 1\,M\Omega$

$R_E = 4\,M\Omega$

$R_C = 3\,M\Omega$

$C_C = 10\,pF$

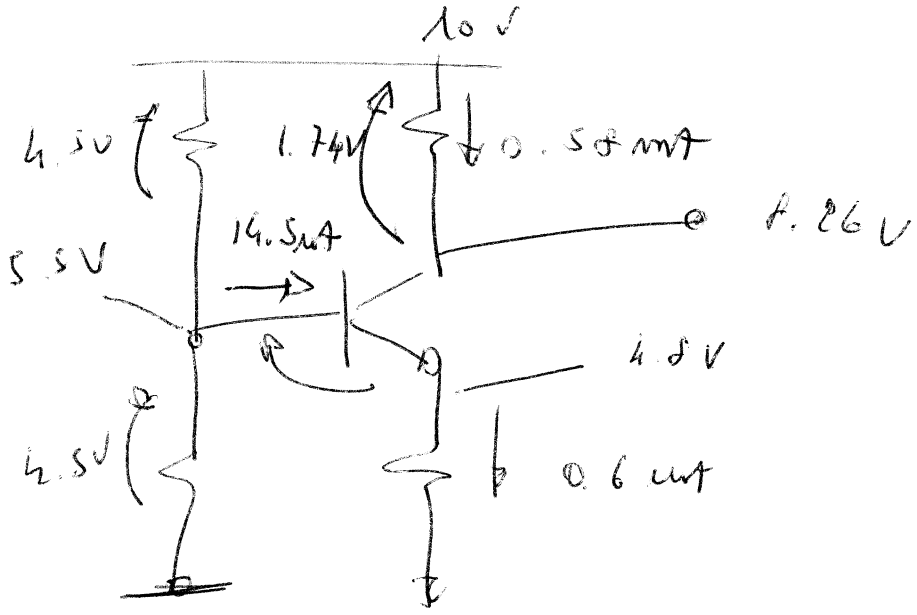
$V_1 = 10V$

$V_p = 1V$

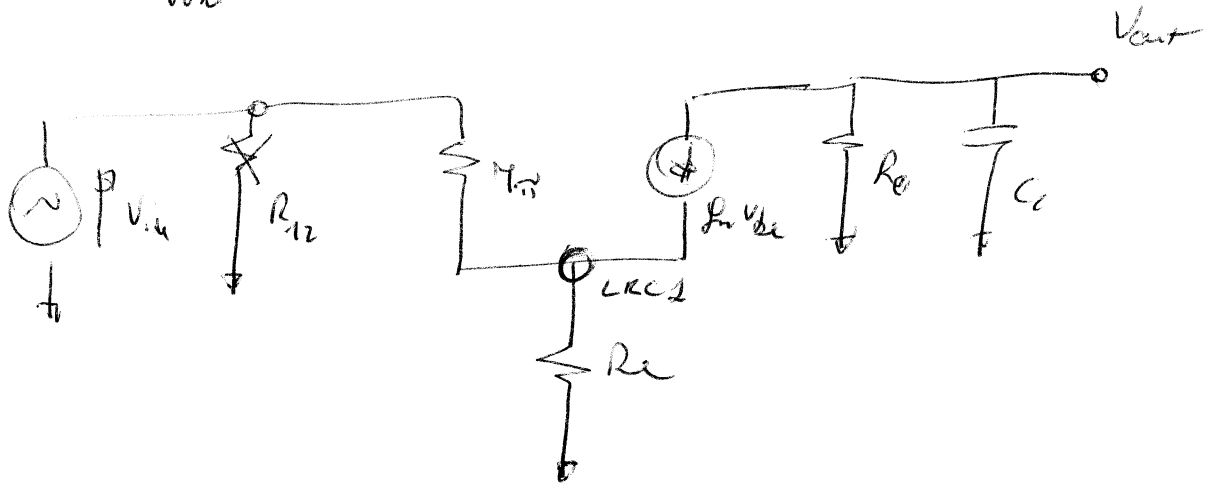
1. Punto op.
2. V_{out}/V_{in} (s)
3) Diagramma di Bode
4) ~~[illegible]~~ VALORE LIMITE di R_C che mantiene il bipolare in zona attiva diretta

---

1) Pto p



8. V_{out}/V_{in}.



$$-V_{out} = -\left(\frac{1}{C}\right) \cdot \frac{R_c}{1+sC_cR_c} = -g_m V_{be} \cdot \frac{R_c}{1+sC_cR_c}$$

$$\begin{cases} V_{be} = V_{in} - V_e \\ \dfrac{V_{be}}{r_\pi} + g_m V_{be} = \dfrac{V_e}{R_e} \quad (\text{LKC1}) \end{cases}$$

$$(V_{in} - V_e)\left(\frac{1}{r_\pi} + g_m\right) = \frac{V_e}{R_e}$$

$$\downarrow$$

$$V_{in}\left(\frac{1}{r_\pi} + g_m\right) = V_e\left(\frac{1}{R_e} + \frac{1}{r_\pi} + g_m\right)$$

$$V_e = \frac{\frac{1}{r_\pi} + g_m}{\frac{1}{R_e} + \frac{1}{r_\pi} + g_m} V_{in}$$

$$V_{be} = V_{in} - V_e = \frac{\frac{1}{R_e}}{\frac{1}{R_e} + \frac{1}{r_\pi} + f_m} V_{in}$$

$$= \frac{r_\pi}{r_\pi + R_e + \frac{\beta}{f_m} f_m R_e} V_{in} \simeq$$

$$= \frac{r_\pi}{r_\pi + \beta R_e} V_{in} \simeq \frac{\frac{1}{f_m}}{\frac{1}{f_m} + R_e} V_{in} =$$

$$= \frac{V_{in}}{1 + f_m R_e}$$

$$\frac{V_{out}}{V_{in}} = - \frac{f_m R_e}{1 + f_m R_e} \cdot \frac{1}{1 + s C_e R_e}$$

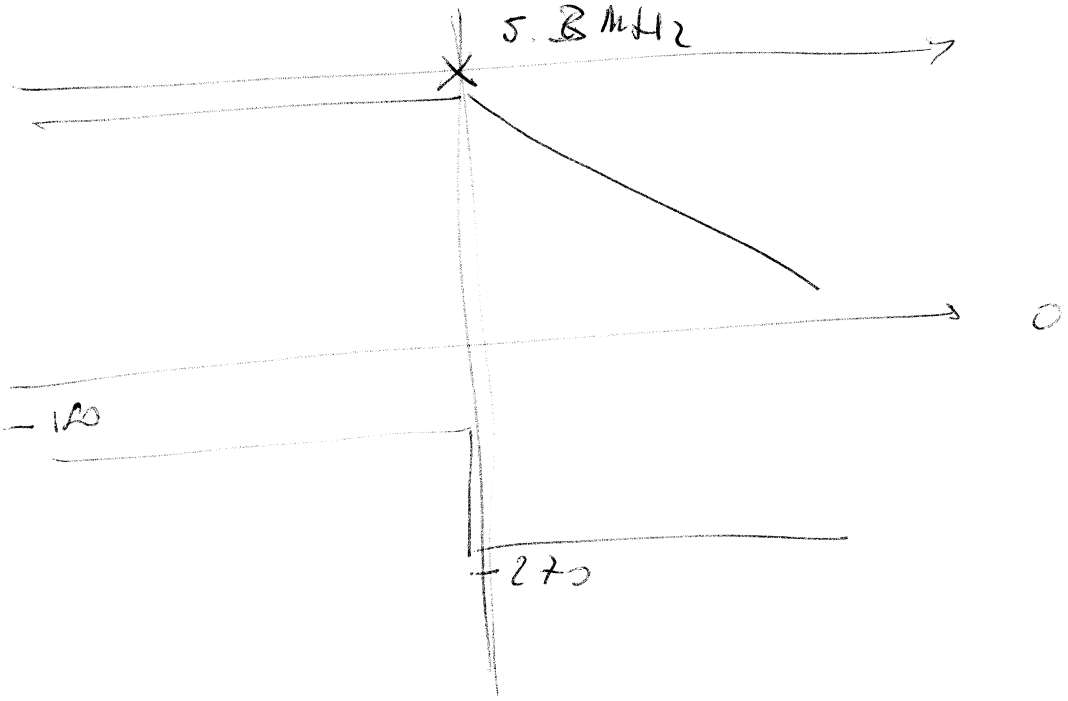
$r_\pi = 1.72 k\Omega$

$f_m = 23.2 \frac{mA}{V}$ $(43\,\Omega)$

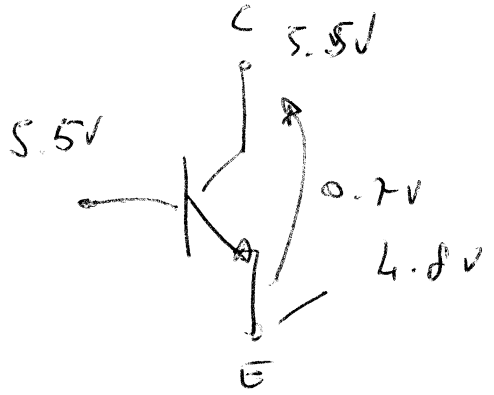
3) BODE

$$\tau_C = R_C \cdot C_C = 30\,\text{ns} \quad (5.3\,\text{MHz})$$

$$-\frac{R_C}{R_E} = 0.37 \quad (-4\,\text{dB})$$



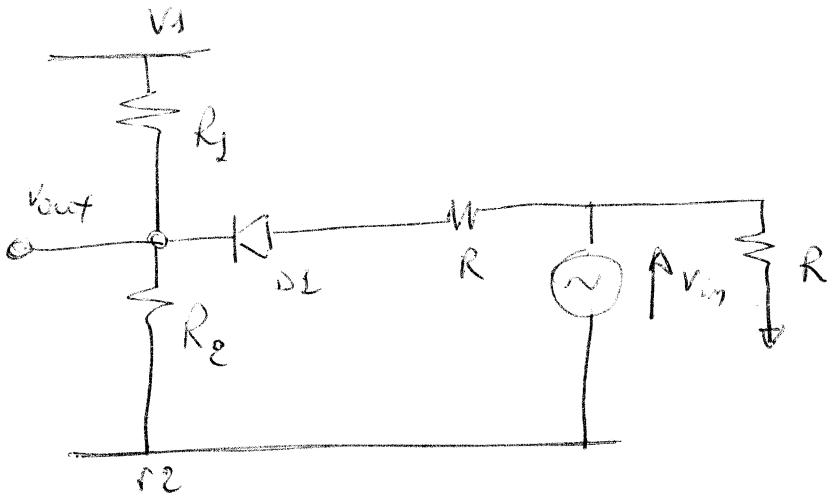
4) VALORE LIMITE DI R_C



$$V_{CE>0} = V_C - V_E = \left(V_1 - R_C I_C\right) - 4.8\,V =$$

$$= \left(10 - R_C \cdot 0.5\,\text{mA}\right) - 4.8\,V > 0 \Rightarrow$$

$$\Rightarrow R_C < \frac{4.5\,V}{0.5\,\text{mA}} = 7.75\,\text{k}\Omega$$

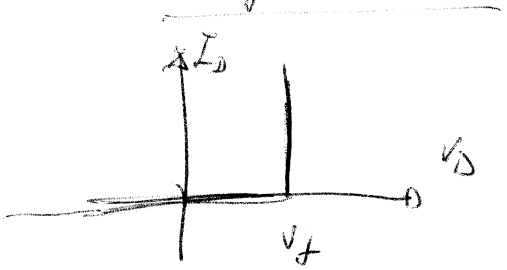


$V_1 = 0\,V \div 2\,V$

$R_1 = R_2 = R = 1\,k\Omega$

$V_2 = 2\,V$

$V_f = 0.7$



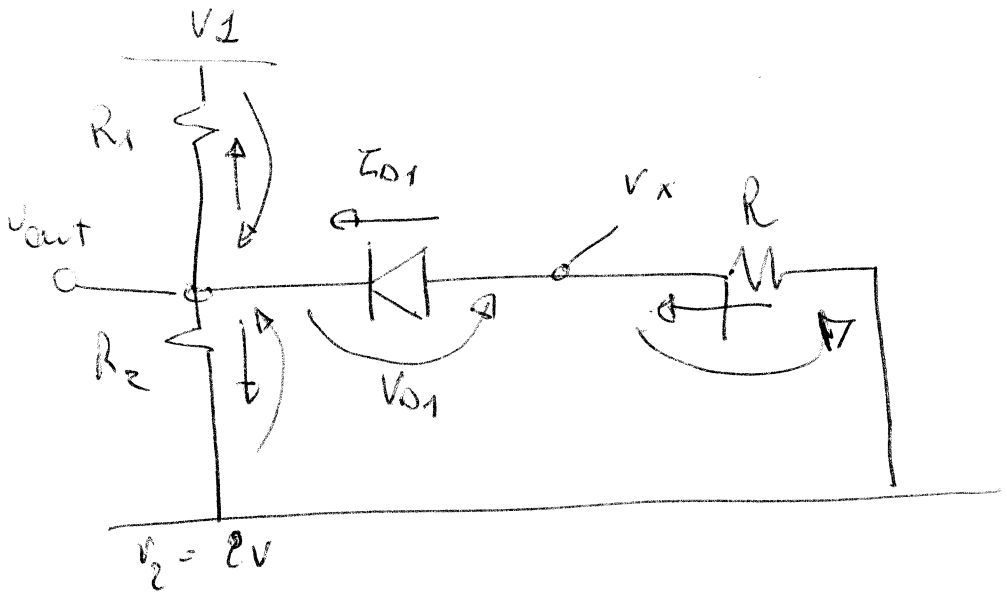
1) I_{D1} per V_1 tra 0 V e 5 V

2) Per $V_1 = 0V$ si calcoli V_{out}/V_{in}

---

1) Ipotesi: diodo ON

$$\begin{cases} I_{D1} > 0 \\ V_{D1} = V_f = 0.7\,V \end{cases}$$



$$\begin{cases} I_{D1} = I_{R1} + I_{R2} = \dfrac{V_{out} - V_1}{R_1} + \dfrac{V_{out} - V_2}{R_2} \quad (> 0 \\ V_{out} = V_x - V_f \\ V_x = V_2 - R I_{D1} \end{cases}$$

$$\begin{cases} V_{out} = (V_2 - R I_{D1}) - V_f \\ I_{D1} = \dfrac{V_{out} - V_1}{R_1} + \dfrac{V_{out} - V_2}{R_2} \end{cases}$$

$R_1 = R_2 = R$

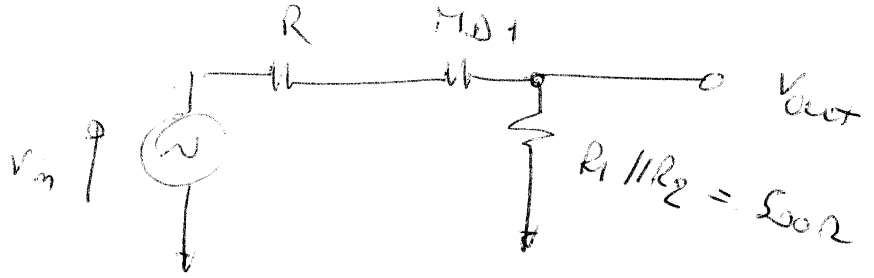
$$I_{D1} = \frac{V_2 - R I_{D1} - V_f - V_1}{R_1} + \frac{V_2 - R I_{D1} - V_f - V_2}{R_2}$$

$$3 I_{D1} = \cdots$$

$$I_{D1} = 2 \frac{V_{out}}{R} - \frac{V_1 + V_2}{R} =$$

$$= 2 \frac{V_2}{R} - 2 \frac{R I_{D1}}{R} - 2 \frac{V_f}{R} - \frac{V_1 + V_2}{R} \Rightarrow$$

$$\Rightarrow 3 I_{D1} = \frac{V_2}{R} - 2 \frac{V_f}{R} - \frac{V_1}{R} > 0$$



$$\frac{V_{out}}{V_{in}} = \frac{R_{12}}{R_{12} + R + r_{D1}} = \frac{R/2}{\frac{3}{2}R + \frac{1}{g_{mD1}}}$$

$$I_{D1} = \frac{V_2 - 2V_f - V_1}{3R} > 0$$

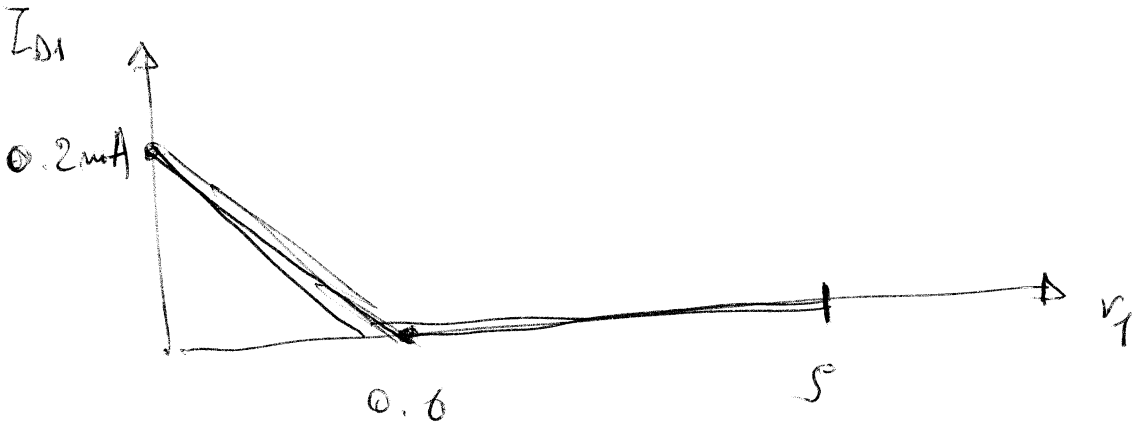
$$V_1 < V_2 - 2V_f = 2 - 2 \times 0.7 = 0.6$$

D1 ON

$V_1 \geq 0.6$ → 2 OFF

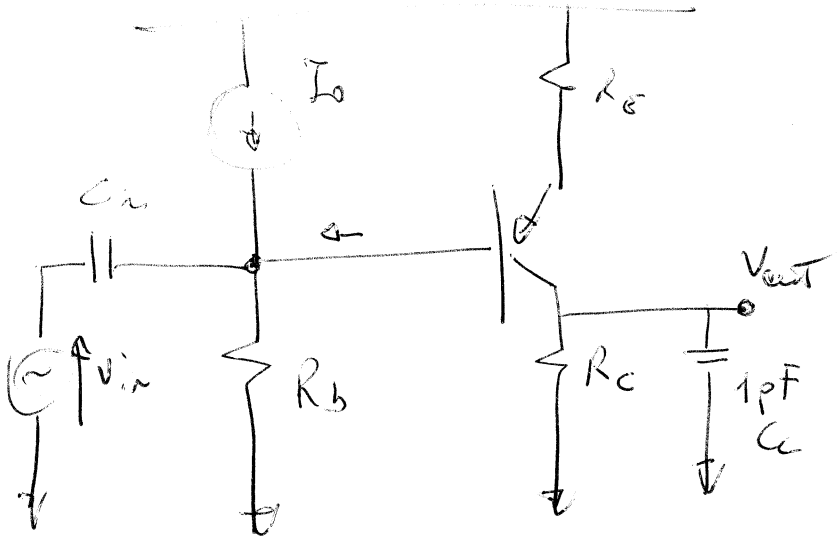
Curva I_{D1} vs V_1

$$I_{D1} = \frac{1}{3}(0.6 - V_1)\ mA$$



2) V_{out}/V_{in} per $V_1 = 0V$

$$g_{fs} = \frac{I_{D1}}{V_{th}} = \frac{0.2mA}{25mV} = 8\ mA/V \quad (125\Omega)$$



$\beta = 100$

$R_b = 2.3\,k\Omega$

$R_E = 2\,k\Omega$

$R_C = 1.2\,k\Omega$

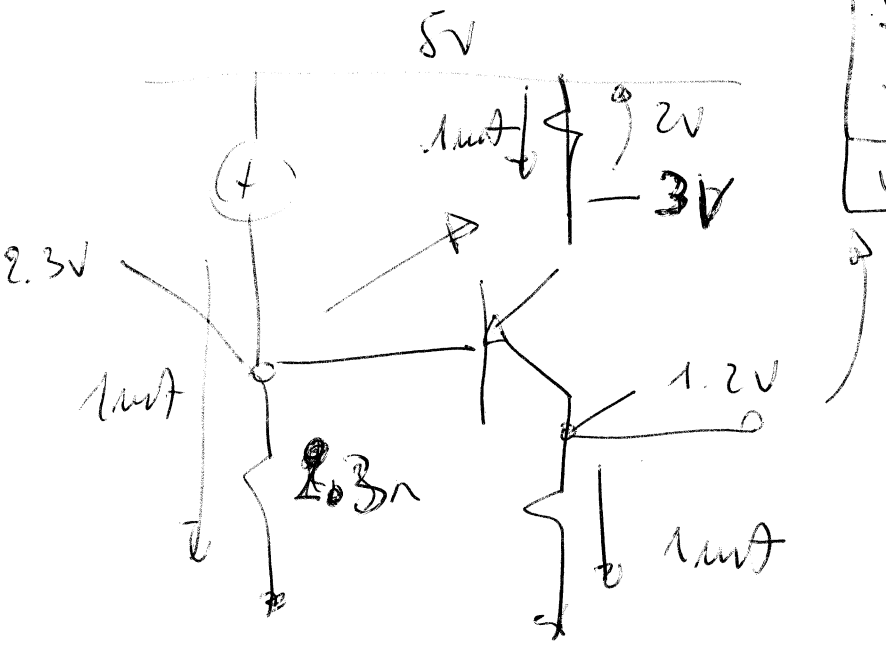
$I_0 = 1\,mA$

$C_{in} = 1\,nF$

$C_C = 1\,pF$

1) Punto OP
2) V_{out}/V_{in} (f)
3) MAX R_C che mantiene il bipolare in saturazione

1) Punto OP



MEGA EQUAZIONE:

$I_0 = \frac{V_B}{R_b} - I_{B_N}$

$I_B = \frac{I_E}{\beta+1}$

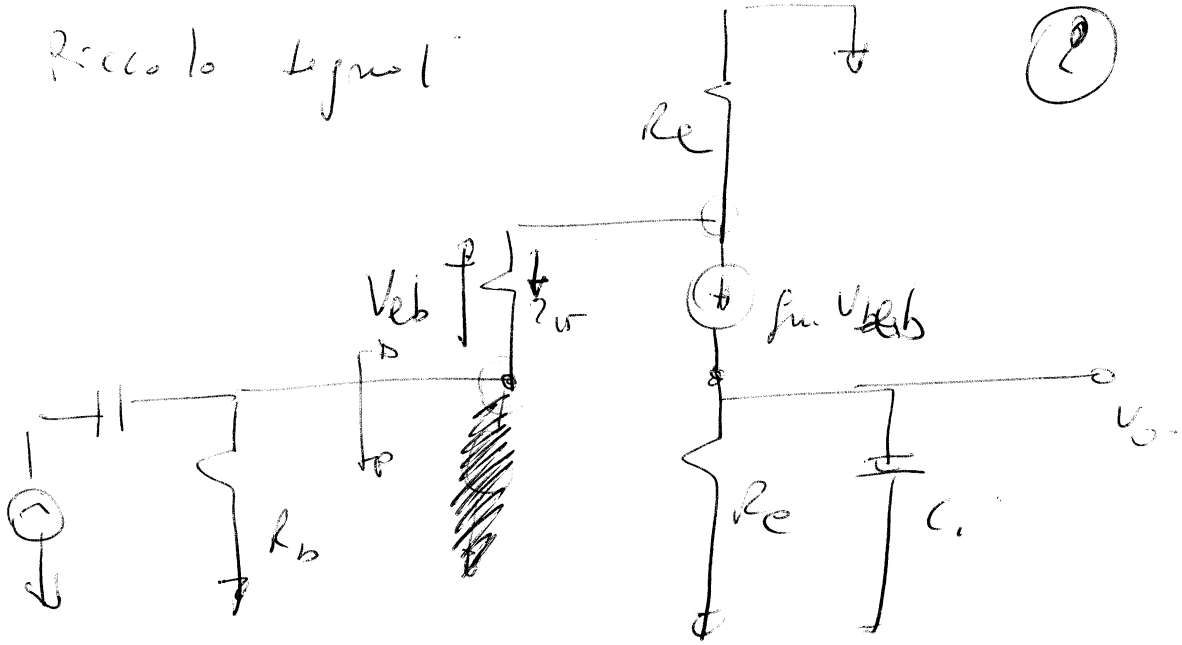
$I_E = \frac{V_{DD} - V_E}{R_E}$

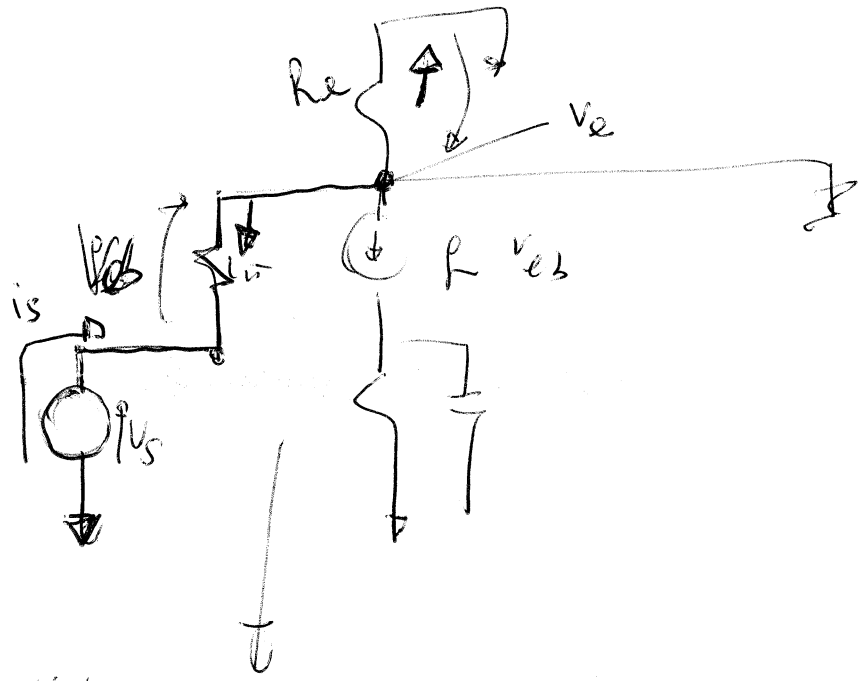
$V_B - V_E = 0.7$

1.5V

$$I_0 = \frac{V_B}{R_b} - \frac{5 - V_B - 0.7}{(\beta+1)\,R_E}$$

c) Piccolo segnale





$$\begin{cases} \dfrac{V_{eb}}{r_\pi} + g_m V_{eb} + \dfrac{V_e}{R_e} = 0 \\ V_{eb} = V_e - V_s \\ i_s = -\dfrac{V_{eb}}{r_\pi} \end{cases}$$

$$-i_s - g_m \frac{r_\pi}{r_\pi} i_s + \frac{V_{eb} + V_s}{R_e} = 0 \longrightarrow$$

$$\cancel{-i_s\left(1 + g_m r_\pi\right) + i_s \frac{r_\pi}{R_e} + \frac{V_s}{R_e} = 0}$$

$$-i_s - g_m v_{gs} i_s - \frac{v_{gs}}{R_\pi} i_s + \frac{v_s}{R_L} = 0$$

$$\frac{v_s}{i_s} = R_L \left(1 + g_m r_\pi + \frac{r_\pi}{R_L} \right)$$

$$i_s = -\frac{v_{eb}}{r_\pi} \longrightarrow v_{eb} = -r_\pi i_s$$

$$\frac{v_{eb}}{r_\pi} + g_m v_{eb} + \frac{v_L}{R_L} = 0$$

$$v_{eb} = v_L - v_s$$

$$-i_s - g_m v_{gs} i_s + \frac{v_{eb} + v_s}{R_L} = 0$$

$$-i_s + g_m r_\pi i_s + \frac{r_\pi}{R_L} i_s = \frac{v_s}{R_L}$$

$$\frac{v_s}{i_s} = R_L + r_\pi + g_m r_\pi R_L$$

$$= \frac{R_L \left(1 + g_m r_\pi \right) + r_\pi}{\simeq \left(3 R_L + \frac{\beta}{g_m} \right)}$$

$$\frac{V_{out}}{V_{in}} = -\frac{\overbrace{s C_{in} R'}^{9.27\mu s\ (70kHz)}}{1 + s C_{in} R'} \cdot \frac{g_m R_C}{1 + g_m R_E} \cdot \frac{1}{1 + s \underbrace{C_c R_C}_{1.2ms\ (132.6Hz)}}$$

$\frac{g_m R_C}{1 + g_m R_E} \simeq 0.6$

$$R' = R_b \parallel \left(\beta R_E + \frac{\beta}{g_m} \right)$$

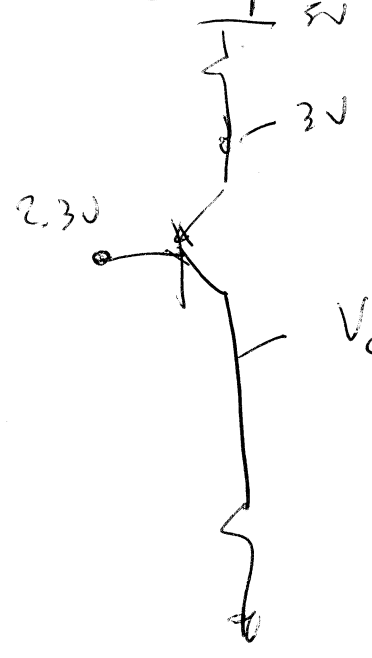
$R_b = 23^3$

$R' \sim 9.27k\Omega$

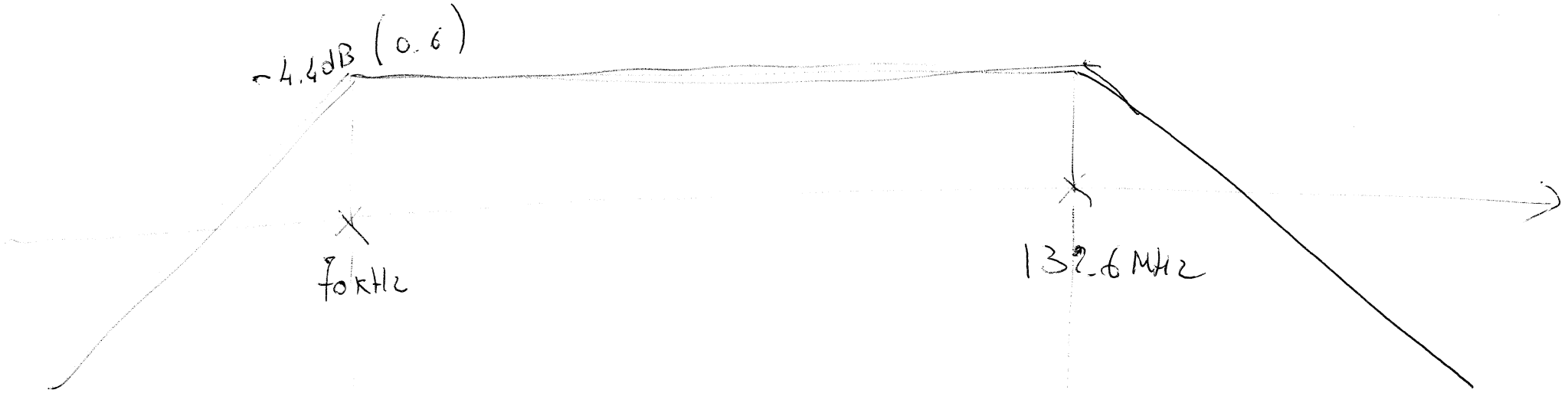
$\left(\beta R_E + \frac{\beta}{g_m} \right) = 202.5k\Omega$

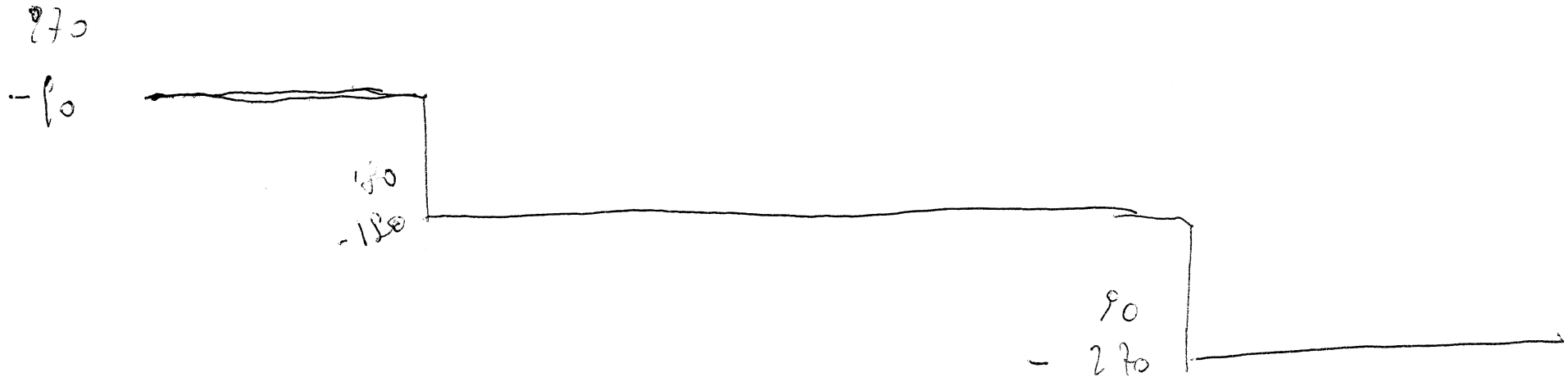
3) Dim R_C in modo che ci sia un guadagno di +3dB — $R_C = 2$

4) Dim R_C per mantenere Q1 in zona attiva



$$R < \frac{1.3}{1mA} = 2.3k\Omega$$


-4.4dB (0.6)
fo kHz
132.6 MHz


?fo
- fo
-50
-130
90
- 2 fo